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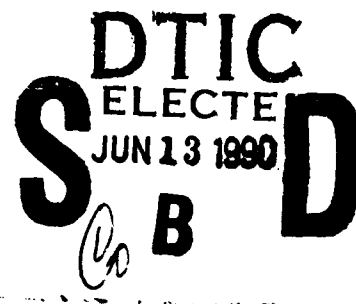
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WORK ENHANCEMENT AND THERMAL CHANGES DURING  
INTERMITTENT WORK IN COOL WATER AFTER CARBOHYDRATE LOADING

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The experiments reported herein were conducted according to the principles set forth in the current edition of the "Guide for the Care and Use of Laboratory Animals," Institute of Laboratory Animal Resources, National Research Council.

This technical report has been reviewed by the NMRI scientific and public affairs staff and is approved for publication. It is releasable to the National Technical Information Service where it will be available to the general public, including foreign nations.

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Commanding Officer  
Naval Medical Research Institute

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exchange ratio (RER) gradually decreased during immersion ( $P < 0.05$ ). Within work periods, RER was higher after TEST than CON ( $P < 0.05$ ). GPS caused significant gastrointestinal distress in 4 subjects, but did not limit their work capacity.

Rectal temperature changed cyclically with rest and exercise for both diets with increases during exercise. Its highest peak was during the second work cycle ( $37.8 \pm 0.1$  and  $37.9 \pm 0.1$  °C for TEST and CON, respectively). By the end of immersion, rectal temperature was significantly lower during exercise for CON ( $37.5 \pm 0.2$  °C), but not for TEST ( $37.7 \pm 0.2$  °C) ( $P < 0.05$ ).

Forearm heat flux changed cyclically with a pattern similar to that for rectal temperature. Peak flux declined from beginning to end of immersion from  $232 \pm 36$  to  $177 \pm 28$  W/m<sup>2</sup> regardless of diet ( $P < .05$ ). By contrast, peak values for thigh heat flux occurred during rest periods and declined only slightly during immersion ( $188 \pm 14$  to  $172 \pm 22$  W/m<sup>2</sup>) regardless of diet.

Our studies showed that during intermittent work in cool water, carbohydrate loading improves the ability to work and has a slight advantage for maintaining core temperature. GPS is not generally well-tolerated as a dietary supplement for carbohydrate loading.

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## INTRODUCTION

Carbohydrate loading has been used to increase the amount of glycogen stored in skeletal muscle. This increase enhances the ability of athletes to engage in prolonged, strenuous activities, such as marathon running, skiing or cycling (1-7).

U.S. Navy divers often engage in strenuous activity in cold water for 2-3 hours or longer. Carbohydrate loading might enhance their ability to work longer and more effectively in these conditions. Increased stores of glycogen in the skeletal muscle could increase the energy supply available for work and for shivering thermogenesis.

When immersed, a diver's metabolism is quite different when compared to the metabolism of athletes and workers in dry environments (8-10). Therefore, the results obtained from dry studies may not be reliable when recommending whether carbohydrate loading would be helpful for divers.

This study was designed to evaluate the effect of carbohydrate loading upon diver performance during immersion in cool water.

## METHODS

Eight active duty U.S. Navy divers participated; their characteristics are listed in Table 1. For each diver, preliminary studies were used to measure oxygen consumption for various workloads on a cycle ergometer while the diver was immersed to his neck in 25 °C water. Maximum oxygen consumption was measured from mixed expired gases and ventilation during a



graded maximum exercise test on the underwater cycle ergometer.

Each diver was trained to work the problems of a computer-assisted performance assessment battery (PAB). The elements of the PAB are described in Table 2.

Each diver was tested twice - once after three days of carbohydrate loading, and once after three days on a control, lower-carbohydrate diet. The tests were counterbalanced, conducted at least one week apart, on the same day of the week, and at the same time of day for each subject.

Each diet (Tables 3 and 4) was nutritionally complete and provided about 3000 Kcal per day. The TEST diet provided at least 600 g of carbohydrate per day; the control diet provided less than 300 g of carbohydrate per day. For each diet, a nutritional beverage (Exceed Nutritional Beverage, Ross Laboratories, Columbus, OH) provided 1420 Kcal and 60 g of protein per day, with all known vitamin and mineral requirements. For carbohydrate loading (TEST diet), a glucose polymer solution (Exceed High Carbohydrate Source) provided 200 - 400 g of additional carbohydrate per day; other high-carbohydrate foods were used as needed to provide extra carbohydrate and calories. For the CONTROL diet, additional low-carbohydrate foods were used as needed. Each subject was given a written menu for each day of the experimental diet; each menu was returned to the investigators with a record of any foods added, substituted or omitted. Testing was done after the diver had been on the experimental diet for three days. Each diver was told not to

use alcohol, tobacco products or caffeine for 24 hours before immersion testing. On the day of immersion testing, each diver consumed the same breakfast (Table 5), ~ 3 h before testing, regardless of which experimental diet he had consumed.

Exercise performance was evaluated as total work completed on a cycle ergometer during immersion. Cognitive performance was assessed by changes in PAB test scores before and after immersion.

For ergometer testing, the subject sat in a semi-recumbent position on a cycle ergometer. The subject was immersed to the neck in water at 25 °C. The immersion protocol was designed with 8 sessions of 10 min rest and 20 min of exercise. Each exercise period consisted of 2 min at a workload of 50 W, 2 min at 100 W, 2 min at a workload halfway between 100 W and the individual's test workload, and 14 min at his test workload. Test workload for each subject was determined in preliminary testing as the cycle workload that would require the individual to work at 80% of maximum oxygen consumption. If the subject could not complete a 20-minute work period, the pattern was changed to 5 min of rest and 10 min of work; in that situation the period of increasing the workload was decreased from 6 to 3 min. The diver was required to pedal at 60 rpm during the work period; inability to maintain that speed was considered the endpoint for determining endurance.

In all cases, the testing was stopped after 4 h of immersion. This work regimen was considered analogous to what

frequently occurs in working dives, where the diver has to perform hard work with intermittent rest periods during a total period of about 4 h. The pattern of shorter work periods was included in order to evaluate whether additional hard work could be accomplished in the event a diver could no longer complete 20-minute work sessions.

During testing, the diver wore a full face mask. Ventilation, oxygen consumption ( $\dot{V}O_2$ ), and carbon dioxide production ( $\dot{V}CO_2$ ) were measured each min by open-circuit spirometry (Metabolic Measuring Cart, Sormedics, Anaheim, CA). The RER was calculated as  $\dot{V}CO_2 / \dot{V}O_2$ . Rectal temperature was measured with a YSI thermistor (Model 401) inserted 20 cm beyond the anal sphincter. Heat flux transducers with embedded thermistor (Model HA13-18-10pP(C)), Thermonetics Corp., San Diego, CA) were used to measure skin temperature and heat flux from the thigh and forearm regions. Rectal temperature ( $T_{re}$ ), thigh heat flux ( $Q_{thi}$ ) and forearm heat flux ( $Q_{arm}$ ) were recorded every 5 min. Voltage output from the thermistors and transducers were amplified and collected on-line with a PDP-1185 computer. Before testing, thermistors were calibrated in a water bath using a quartz thermometer as the reference temperature. Heat flux transducers were calibrated with a Rapid-K thermal conductivity instrument (Dynatech Corp., Cambridge, MA). Electrocardiogram was monitored continuously for heart rate.

Blood samples were obtained by sterile venipuncture just before and just after immersion to measure changes in hematocrit,

hemoglobin, serum glucose, urea nitrogen, sodium, potassium, chloride, and bicarbonate.

The sequence of events for each test day is listed in Table 6.

Data were analyzed by multivariate analysis with post hoc testing to identify differences among time periods. Data are presented as the mean  $\pm$ SEM, and  $p$  values  $< 0.05$  were considered to represent significant differences.

## RESULTS

Four subjects completed all 8 work sessions after both diets; 3 completed all 8 sessions after carbohydrate loading (TEST) but not after the CONTROL diet. One subject completed 7 sessions after carbohydrate loading, and 6 after the CONTROL diet (Table 7).

All subjects completed the first 6 rest-work cycles for both diets. Statistical analysis of respiratory and thermal data was limited to data collected during these 6 cycles. Differences between diets for oxygen consumption, carbon dioxide production, and min ventilation were not significantly different (Figures 1 and 2). Figure 3 illustrates that exercise RER significantly decreased during immersion for both diets. However, with the exception of the first exercise period, exercise RER was significantly higher after carbohydrate loading vs. control ( $P < .05$ ).

Rectal temperature changed cyclically with rest and work (Figure 4). Its highest peak was during the second work cycle

with both diets ( $37.8 \pm 0.1$  °C and  $37.9 \pm 0.1$  °C for TEST and CONTROL, respectively). Subsequently, exercise Tre declined significantly by the end of immersion after the CONTROL diet (final Tre  $37.5 \pm 0.2$  °C), but not after the TEST diet (final Tre  $37.7 \pm 0.2$  °C).

Arm heat flux (Figure 5) had a cyclic pattern similar to that for rectal temperature, with increases during exercise. No significant differences occurred with respect to diet. For both diets, peak  $Q_{arm}$  declined significantly during immersion from  $232 \pm 36$  ( $W/m^2$ ) to  $177 \pm 28$  ( $P < .05$ ). Figure 6 illustrates that thigh heat flux was similar between diets. In contrast to the arm, peak values for thigh heat flux occurred during rest (Figure 6), and they declined only slightly during immersion from  $188 \pm 14$   $W/m^2$  to  $172 \pm 22$   $W/m^2$ .

All subjects experienced shivering and reported being cold during the first 10 min rest period. They also reported that it was much more difficult to complete the first work period than most of the subsequent periods. After the first work period, there was less shivering and the subjects reported that they did not feel as cold and that the subsequent work periods were somewhat easier. Oxygen consumption was greater than 90% of maximum during the first work period; it approximated 80% of maximum during subsequent work periods (see Figure 1).

Performance on the PAB was unaffected by either diet or immersion. Compared to baseline performance, the latency of response time and percentage of correct answers were unchanged

before and after immersion, and regardless of diet.

The glucose polymer solution used with the TEST diet was not well tolerated by some subjects; the CONTROL diet was well tolerated by all subjects. Three subjects had no gastrointestinal problems while on the TEST diet, one had minimal complaints of gas, one was mildly uncomfortable due to gas, and three had significant problems with loose stools and gas. Despite these complaints, all subjects were able to consume the TEST diet and complete the immersion testing as required.

The serum electrolytes and chemistries, hematocrit, and hemoglobin were within the range of normal values before and after immersion.

#### DISCUSSION

Carbohydrate loading improved the ability of these divers to complete a task that was designed to simulate the type of demanding work regimen that might exist during a working dive. Seven of 8 were able to complete the work after carbohydrate loading, but only 4 completed all 8 work sessions after the control diet. The eighth diver completed more work after carbohydrate loading than after the control diet (7 vs. 6 work sessions).

Because each immersion was terminated after 8 work sessions, it is impossible to quantitate the total benefit of carbohydrate loading; most likely, the actual benefit was underestimated. The 7 divers who completed all 8 work sessions after carbohydrate loading could have worked longer, but how much longer they could

have worked is unknown. By contrast, only 4 divers might have been able to complete more than 8 work sessions after the control diet. It is important to recognize that each 20-min session with 14 min continuously working at nearly maximal aerobic capacity represents substantial effort by the diver. The fact that half of the divers were able to complete one or two extra work sessions reflects a significant physiologic benefit from carbohydrate loading. The benefit of carbohydrate loading is further supported by the fact that none of the divers did better after the control diet compared to carbohydrate loading. The results of this study indicate that carbohydrate loading can be used to improve divers' performance under operational conditions.

Gastrointestinal distress was frequently caused by the glucose polymer solution used to supplement carbohydrate intake. Other foods that can be used for carbohydrate loading would be tolerated better, and other diets that do not require the glucose polymers should be developed.

During work and rest under immersed conditions, the  $\dot{V}O_2$  and  $\dot{V}CO_2$ , were not significantly different between diets. However, small differences in these variables resulted in a significantly higher RER with the high carbohydrate diet. This higher RER with the test diet indicates that, compared to fat, the body stores of carbohydrate provided a higher proportion of the energy used for work.

There was no dramatic effect of diet upon thermal balance, but the data suggest that carbohydrate loading might help to

maintain body temperature during cold immersion.. Rectal temperature declined more during immersion after CONTROL diet than after carbohydrate loading. Although it was statistically significant, the difference was only 0.2 °C. It is possible that under more extreme conditions, i.e., colder temperatures, the benefit of carbohydrate loading would be greater and more beneficial. The availability of increased muscle glycogen from carbohydrate loading would be expected to provide this benefit by providing more energy for shivering thermogenesis. Further studies are required to evaluate this possibility.

The initial rest period in cool water had an adverse effect upon the divers' ability to complete the first work session. It appears that relatively small amounts of cooling (the water temperature in this study was not severely cold) results in a condition where the chilled diver will have to expend more energy to accomplish a given amount of work than would be required without chilling. During the first work session, there apparently was adequate heat production to warm the muscles so that the mechanical efficiency of subsequent work periods was improved. This finding indicates that strategies should be developed to prevent chilling before heavy work is attempted.



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#### LAY LANGUAGE SUMMARY

Eight U.S. Navy divers participated in a study to determine whether a carbohydrate loading diet would improve their ability to perform intermittent hard work while immersed in cool water. Dietary effects upon body temperature regulation were also studied. Each diver was tested once after 3 days of carbohydrate loading with a test diet that contained 600 g of carbohydrate per day, and once after 3 days on a control diet that contained less than 300 g of carbohydrate per day.

Each diver sat immersed to the neck in water at 25 °C (77 °F) and repeated a pattern of 10 min rest then 20 min pedalling an underwater cycle ergometer until he could no longer complete a 20-minute work session or until 8 sessions had been completed. The ergometer was set at a workload that would require the individual to work at 80% of his maximal aerobic capacity.

Carbohydrate loading improved the ability of these divers to complete a task that was designed to simulate the type of demanding work regimen that might exist during a working dive. Seven of 8 were able to complete the work after carbohydrate loading, but only 4 completed all 8 work sessions after the control diet. The eighth diver completed more work after carbohydrate loading than after the control diet (7 vs. 6 work sessions).

Because each immersion was terminated after 8 work sessions, it is impossible to quantitate the total benefit of carbohydrate loading; most likely, the actual benefit was underestimated. The

7 divers who completed all 8 work sessions after carbohydrate loading could have worked longer, but how much longer they could have worked is unknown. By contrast, only 4 divers might have been able to complete more than 8 work sessions after the control diet. It is important to recognize that each 20-minute session with 14 minutes continuously working at nearly maximal aerobic capacity represents substantial effort by the diver. The fact that half of the divers were able to complete one or two extra work sessions reflects a significant physiologic benefit from carbohydrate loading. The benefit of carbohydrate loading is further supported by the fact that none of the divers did better after the control diet compared to carbohydrate loading. The results of this study indicate that carbohydrate loading can be used to improve divers' performance under operational conditions.

The oxygen consumption, carbon dioxide production, and minute ventilation were not significantly different between diets. The volume of carbon dioxide produced per liter of oxygen consumed was significantly increased by carbohydrate loading. This indicates that, compared to fat and protein, the body stores of carbohydrate provided a higher proportion of the energy used for work after the diver had been on the test diet compared to control.

There was no dramatic effect of diet upon thermal balance, but the data suggest that carbohydrate loading might help to maintain body temperature during cold immersion. Rectal temperature declined more during immersion after control diet

than after carbohydrate loading. Although it was statistically significant, the difference was only 0.2 °C. It is possible that under more extreme conditions, i.e., colder temperatures, the benefit of carbohydrate loading would be greater and more beneficial. The availability of increased muscle glycogen from carbohydrate loading would be expected to provide this benefit by providing more energy for shivering thermogenesis. Further studies are required to evaluate this possibility.

The initial rest period in cold water resulted in a small amount of cooling (the water temperature in this study was not severely cold) that required the diver to expend more energy during the first work period compared to subsequent work periods. The results indicate that strategies should be developed to prevent chilling before heavy work is attempted.

Gastrointestinal distress was a common complaint with the test diet, primarily caused by the glucose polymer solution used to increase carbohydrate intake. Other foods that could be used for carbohydrate loading would be tolerated better.

Table 1. Characteristics of divers who participated  
in carbohydrate-loading study.

SUBJECT	AGE (YR)	HT (CM)	WT (KG)	% BODY FAT	MAX O <sub>2</sub> (l/min)	MAX WORK (W)	TEST WORK (W)
A	27	172	75.4	15	3.22	225	170
B	24	173	85.4	14	3.81	185	150
C	29	177	79.3	16	3.03	165	130
D	37	184	88.3	22	3.07	180	145
E	27	176	91.6	21	3.23	210	165
F	30	170	73.9	15	2.74	165	130
G	29	167	69.0	17	2.96	175	140
H	35	170	70.2	15	2.97	175	140
MEAN	28	175	79.1	17	3.13	185	145
SEM	2	2	3.0	1	0.10	8	5

Table 2. Performance assessment battery used to evaluate performance before and after immersion. The battery includes eight tests and requires about thirty minutes to complete.

#### INDIVIDUAL TEST

1. STERNBERG MEMORY SEARCH: measures short-term memory, encoding, recognition, and response speed.
2. GRAMMATICAL REASONING: measure logical reasoning, recognition of relationships, concept manipulation, and temporal-spatial relationships.
3. MANIKIN TEST: measures recognition of spatial orientation and 3-dimensional orientation of visual stimulus.
4. PATTERN COMPARISON: measures visual nonverbal pattern matching.
5. STROOP COLOR NAMING: measures response-competition interference, and ability to inhibit preferred response.
6. MATCHING TO SAMPLE: measures visual nonverbal pattern matching, and 2-choice recognition memory.
7. LETTER SEARCH: measures sustained attention/concentration, visual scanning efficiency, and target recognition.
8. REPEATED ACQUISITION: measures short-term memory.

Table 3. Daily menu for test diet to provide 600 grams of carbohydrate per day with no known nutrient deficiency.

- I. Four 8-ounce cans of EXCEED NUTRITIONAL BEVERAGE\* to provide 1420 Kcal, 200 grams of carbohydrate, 60 grams of protein and recommended daily allowance of vitamins and minerals.
- II. One quart (one packet diluted in water to equal 32 ounces of beverage) of EXCEED HIGH-CARBOHYDRATE SOURCE.\*
- III. Either of the following:
  - A. A second quart of EXCEED HIGH-CARBOHYDRATE SOURCE
  - B. Any four units from among the following: (can be repeats of the same item such as four units of canned fruit to total 32 ounces).
    1. CANNED FRUIT IN HEAVY SYRUP - 8 OUNCES (fruit cocktail, apricots, pears, pineapple, or applesauce).
    2. FRESH FRUIT UNCOOKED (NUMBER GIVEN IS ONE UNIT) (3 apples or 3 oranges or 2 pears or 2.6 ounces of seedless raisins).
    3. POTATO - 3 POTATOES BAKED OR BOILED (with any amount of butter, sour cream or other condiment).
    4. FRUIT PIE - 4.5 OUNCES PER SERVING (apple, cherry, mince, lemon meringue).
    5. BREAKFAST CEREAL PREPARED AS FOLLOWS PLUS ANY SWEETENER: Corn, wheat or rice as flakes or chexs - 2 ounces with 6 ounces of skim or 2% milk.
    6. JAM OR JELLY SANDWICH TO CONTAIN: 2 tablespoons of any fruit jam or jelly and 2 slices of any bread (may add peanut butter).
- IV. MAY EAT ANY OTHER ADDITIONAL FOODS AS LONG AS THE ABOVE REQUIREMENTS ARE MET AND ADDITIONAL FOODS OR BEVERAGES DO NOT CONTAIN CAFFEINE.

\*EXCEED NUTRITIONAL BEVERAGE and EXCEED HIGH-CARBOHYDRATE SOURCE are products of Ross Laboratories, Columbus, Ohio 43215.



Table 4. Daily menu for control diet to provide no more than 300 grams of carbohydrate per day with no known nutrient deficiency.

- I. Four 8-ounce cans of EXCEED NUTRITIONAL BEVERAGE to provide 1420 Kcal, 200 grams carbohydrate, 60 grams of protein and recommended daily allowance of vitamins and minerals.
- II. Any three of the following (Can be repeats of the same item such as three sandwiches).

A. SANDWICH OPTIONS (PER SANDWICH)

1. No more than two slices of bread.
2. Butter, mustard, mayonnaise, lettuce or tomatoe as desired.
3. MUST NOT USE ONIONS.
4. ONE of the following
 

a. Boiled ham	5.5 oz **
b. Cheddar cheese slices	3.5 oz
c. Swiss cheese slices	3.5 oz
d. Hamburger	4.5 oz **
e. Chicken salad	6.0 oz **
f. Tuna salad	5.0 oz **

B. McDONALD'S QUARTER POUNDER WITH CHEESE

C. BREAKFAST

1. Two or more eggs, fried or scrambled \*\*
2. EITHER 4 or more slices of bacon \*\*
3. NO MORE THAN ONE plain muffin OR bagel OR slice of toast

D. NUTS (One of the following SHELLED with NO SWEETENING)

- |            |        |
|------------|--------|
| 1. PECANS  | 2.4 oz |
| 2. WALNUTS | 2.7 oz |
| 3. PEANUTS | 3.0 oz |

E. OTHER POSSIBLE FOODS INCLUDE:

- |                       |           |
|-----------------------|-----------|
| 1. Frankfurter        | 3 oz **   |
| 2. Hamburger          | 6 oz **   |
| 3. Steak (beef)       | 4.6 oz ** |
| 4. Roast beef         | 9 oz **   |
| 5. Chicken breast     | 10 oz **  |
| 6. Chicken drumstick  | 12 oz **  |
| 7. Breaded fishsticks | 10 oz     |

III. FOR ITEMS MARKED WITH DOUBLE ASTERISK (\*\*), MORE THAN THE AMOUNT LISTED MAY BE CONSUMED.

IV. NONE OF FOLLOWING SHOULD BE CONSUMED EXCEPT FOR THE AMOUNTS ALLOWED ABOVE.

BREADS  
ROLLS  
CAKES  
PIES  
PUDDINGS  
NOODLES  
PASTA  
POTATOES  
CHIPS  
ICE CREAM  
ANY CANDY

Table 5. Menu for breakfast to be eaten on day of immersion test.

1 toasted whole grain bagel, 1 pat butter, grape jelly  
1 cup orange juice  
1 banana  
1 cup decaffeinated coffee or tea, 2 oz lowfat milk

Table 6. Schedule of events for day of immersion testing.

Time (h:m)	
0:00	Void, weight, insert rectal probe, drink water equal to 0.5% of body weight
0:30	Attach electrodes and thermistors
1:00	Performance Assessment Battery Obtain 20-ml blood sample
1:50	Dry resting evaluation of electrode signals and breathing apparatus for 10 min
2:00	Enter immersion tank Rest
2:10	Begin first work period
6:00	End last work period Leave immersion tank
6:10	Obtain 20-ml blood sample Performance Assessment Battery
6:45	Body weight End of testing

Table 7. Work completed on underwater cycle ergometer after CONTROL (CONT) or TEST (carbohydrate loading) diet.

SUBJECT	NUMBER OF 20-MIN SESSIONS COMPLETED		TOTAL WORK DURING ENTIRE TEST SESSION (WATT-MIN)	
	TEST	CONT	TEST	CONT
A	7	6	20725	19628
B	8	7	19896	19194
C	8	8	17874	17814
D	8	6	19360	18364
E	8	8	21608	21599
F	8	6	17705	16540
G	8	8	18943	18860
H	8	8	18863	18943
MEAN			19372	18868*
SEM			474	516

\*P < 0.05 from TEST diet

## FIGURE LEGENDS

- Figure 1. Oxygen consumption for 10 min pre-immersion and for first 6 cycles of 10 min rest followed by 20 min of work on a cycle ergometer during head-out immersion. Values are mean of observations on eight subjects. Time 0 is when immersion and first 10-minute rest period started.
- Figure 2. Minute ventilation for 10 min pre-immersion and for first 6 cycles of 10 min rest followed by 20 min of work on a cycle ergometer during head-out immersion. Values are mean of observations on 8 subjects. Time 0 is when immersion and first 10-minute rest period started.
- Figure 3. Respiratory Exchange Ratio (RER) for 10 min pre-immersion and for first 6 cycles of 10 min rest followed by 20 min of work on a cycle ergometer during head-out immersion. Values are mean of observations on 8 subjects. Time 0 is when immersion and first 10-minute rest period started. Downward deflection in RER occurred at the start of exercise, and upward deflections at the end of exercise; reflecting transient imbalances in body CO<sub>2</sub> stores.
- Figure 4. Rectal temperature for 10 min pre-immersion and for first 6 cycles of 10 min rest followed by 20 min of work on a cycle ergometer during head-out immersion. Values are mean of observations on 8 subjects. Time 0 is when immersion and first 10-minute rest period started.
- Figure 5. Forearm heat flux for 10 min pre-immersion and for first 6 cycles of 10 min rest followed by 20 min of work on a cycle ergometer during head-out immersion. Values are mean of observations on 8 subjects. Time 0 is when immersion and first 10-minute rest period started.
- Figure 6. Thigh heat flux for 10 min pre-immersion and for first 6 cycles of 10 min rest followed by 20 min of work on a cycle ergometer during head-out immersion. Values are mean of observations on 8 subjects. Time 0 is when immersion and first 10-minute rest period started.

FIGURE 1

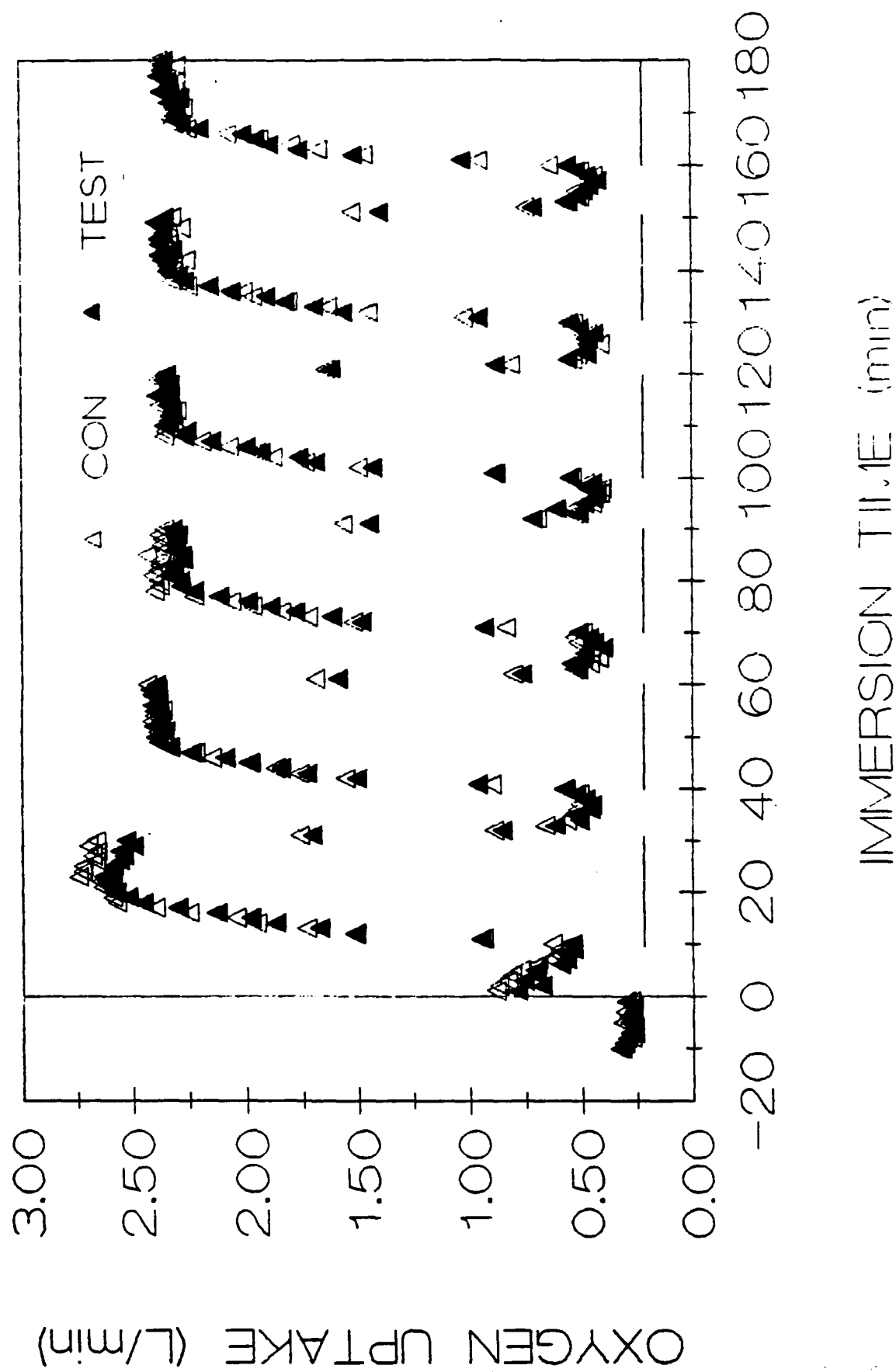


FIGURE 2

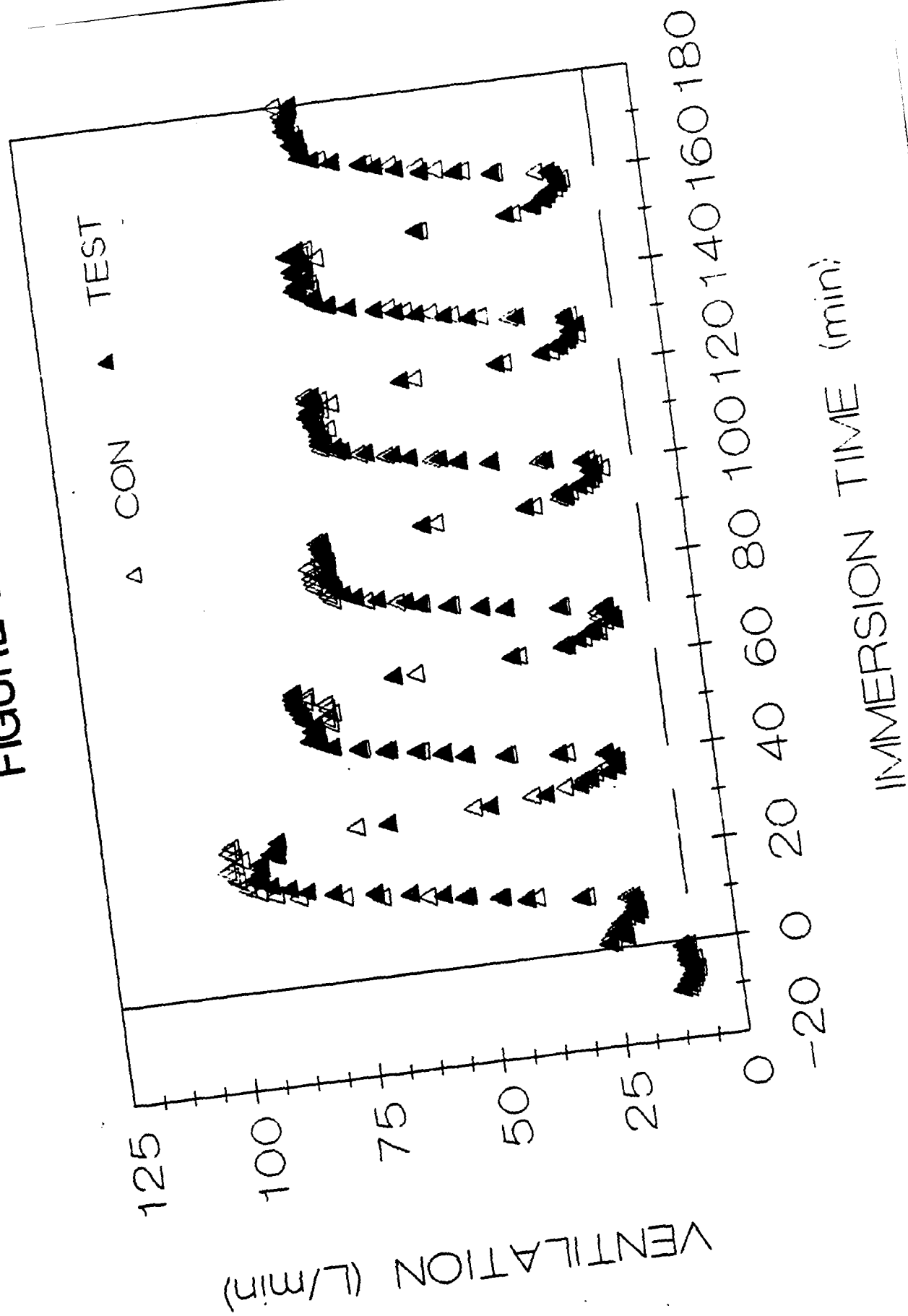




FIGURE 3

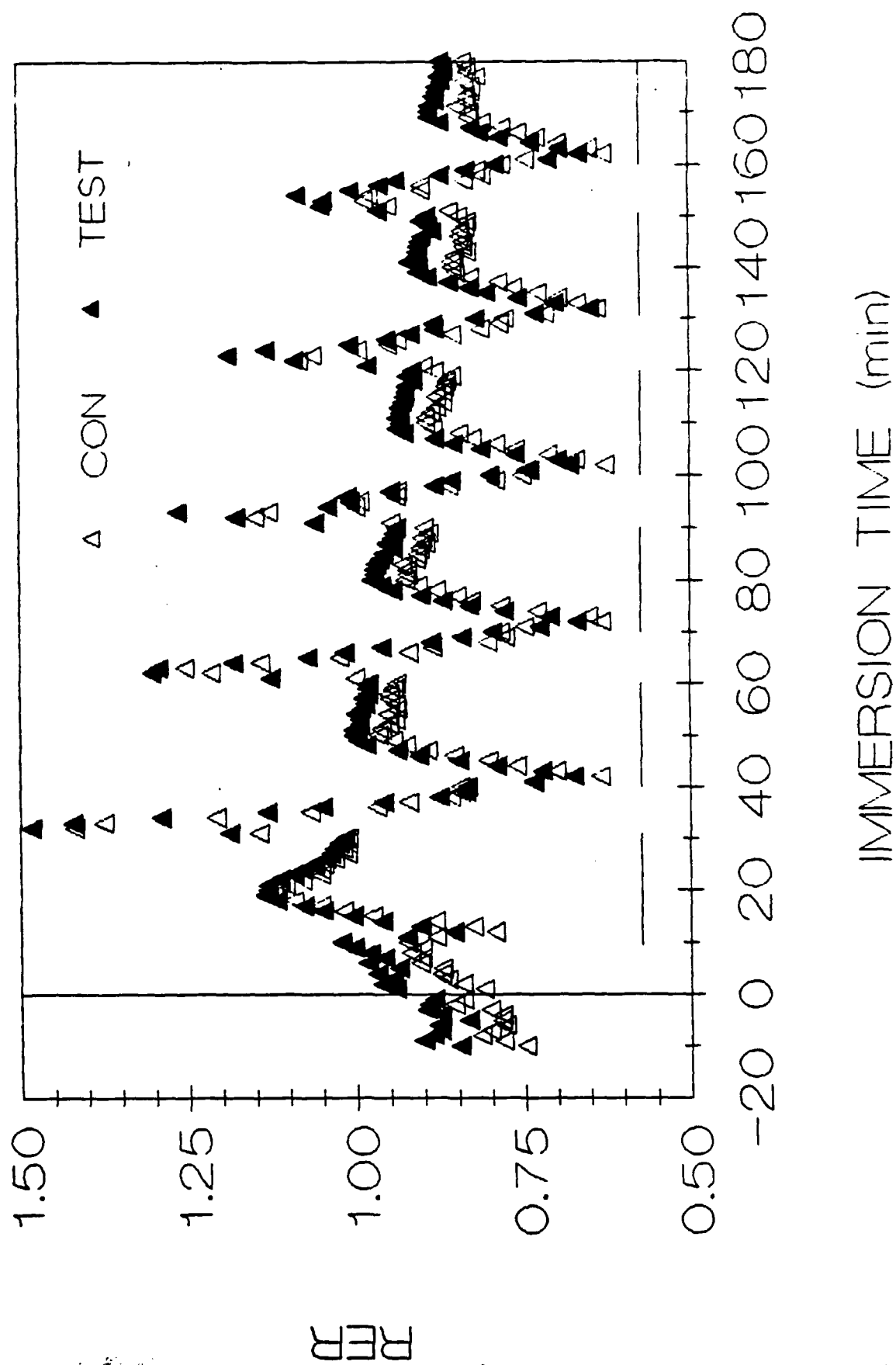


FIGURE 4

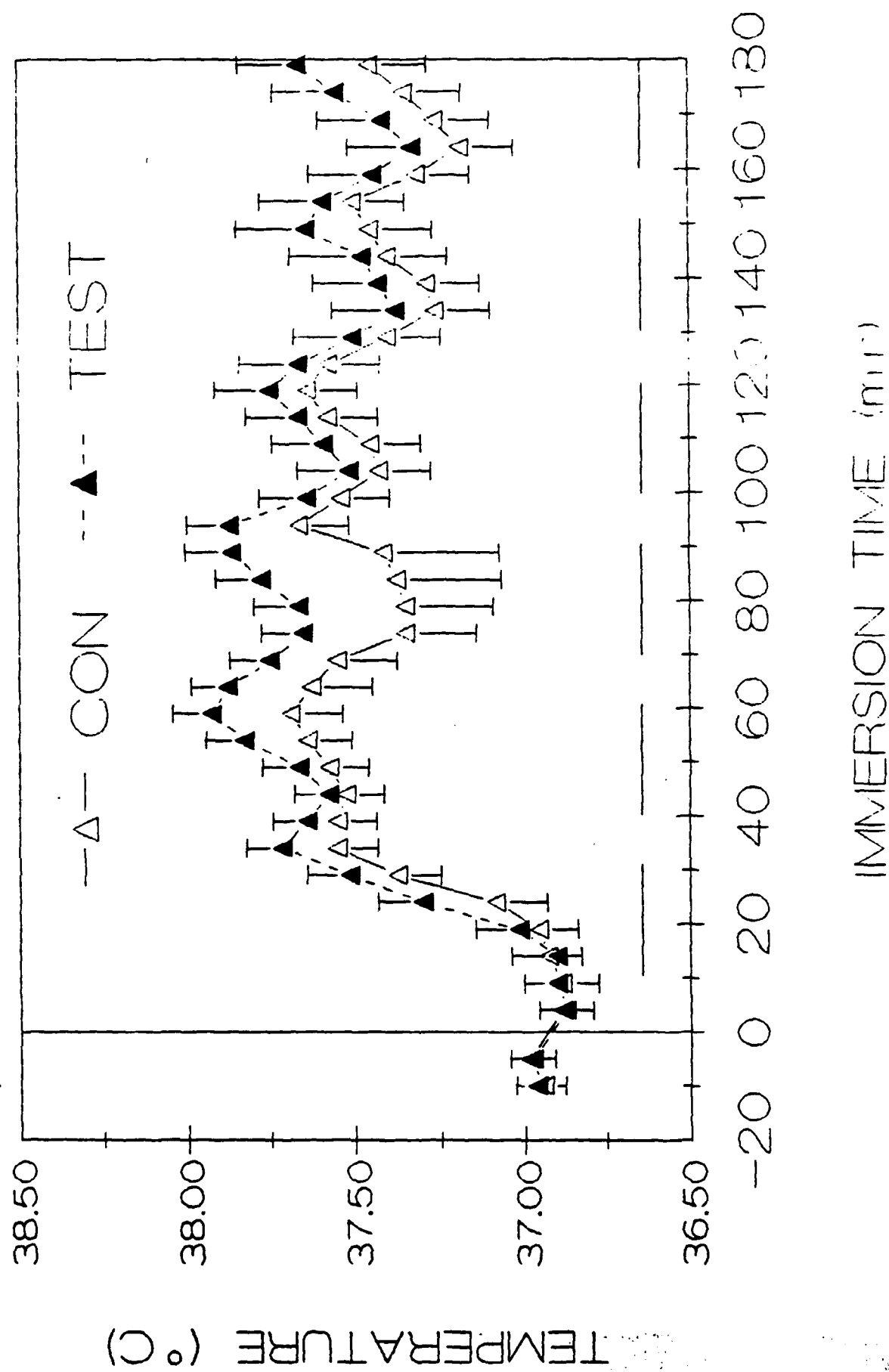


FIGURE 5

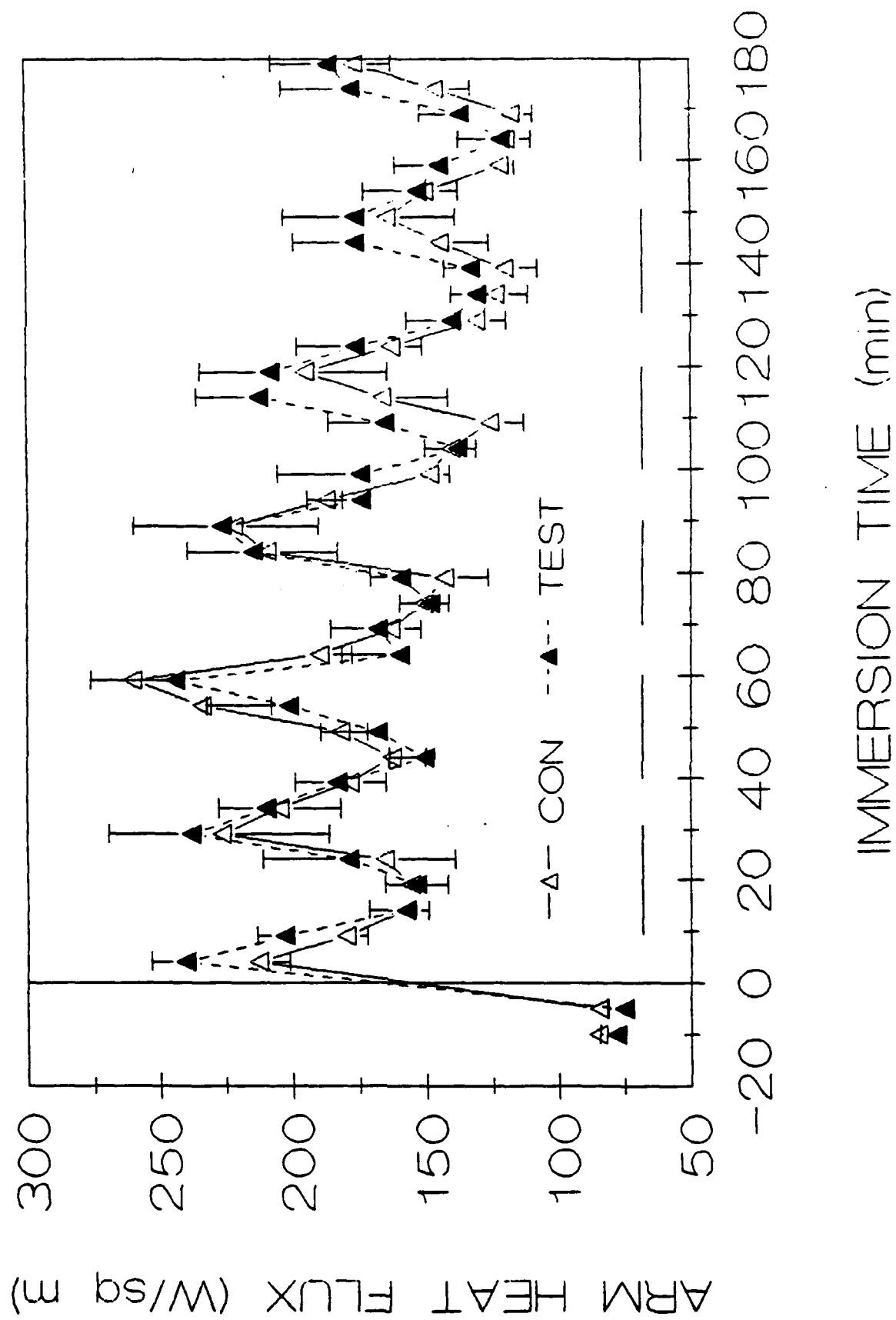


FIGURE 6

